Thesis/
Reports
Roundy, B.A.

ENVIRONMENTAL AND ECOLOGICAL FACTORS THAT INFLUENCE COMMUNITY SUSCEPTIBILITY TO INVASIVE PLANT SPECIES

Final Report for Research Joint Venture Agreement 01-JV-11222074-526

Title: Environmental and ecological factors that influence community susceptibility to invasive plant species

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Executive Summary:

Purpose: This research was funded as a subcontract to a larger research project to determine the effects of elevation and disturbance on cheatgrass invasion. The purpose of this subcontracted research was to measure soil water and temperature on study sites to determine the effects of elevation and disturbance on these environmental variables and in relation to cheatgrass invasion.

Work Performed: Soil water sensors were installed on 6 treatment plots at 3 soil depths and on 3 replications at 9 sites in Nevada and Utah (total = 648 gypsum block soil water sensors + 216 additional watermark sensors installed at the 1-3 cm depth = 864 total soil water sensors installed). Fine-wire thermocouples were also installed on 6 treatment plots at 3 soil depths and on 2 replications at each of 9 sites (total = 432 sensors). Air temperature and precipitation gages were also installed at all 9 sites. All sensors were ready every minute and hourly averages (or totals for precipitation) recorded with electronic multiplexers and microloggers for 4 fall (2001, 2002, 2003, 2004) and 4 spring (2002, 2003, 2004, 2005 seasons). This constitutes the most intense soil water and temperature data set across an elevational gradient for sagebrush ecosystems that has ever been collected. The data collection systems are still in place and will continue to add to this data set.

Contribution: The environmental data were used as a support for interpretation of success or failure of cheatgrass seeded on subplots to establish in 2002 and 2003 on disturbed and undisturbed plots (Chambers et al. 2006). The 4 years of data are also being used to assess fall and spring cheatgrass germination potential in relation to year, elevation, and disturbance (see attached expanded abstract). A manuscript reporting these data and analysis will be submitted for publication fall 2005. In addition, an MS thesis and subsequent journal paper are being prepared to report soil water availability in relation to year, site, elevation, and disturbance. Those publications should be submitted in spring 2006. This extensive data set also provides the foundation for an ongoing research effort to develop heat accumulation models of germination and seedling root growth for weeds and desirable native revegetation species. Field temperature curves from this study are currently being used to test these heat accumulation models in the laboratory, and in the field. Weed and desirable species germination and seedling root growth responses can then be used to predict seedling establishment or failure in the field based on field data from this study and from future studies. This will allow us to determine the potential for weedy and desirable species to establish in fire rehabilitation plantings for certain sites and elevations. Beside the 3 publications mentioned above, future publications using data generated from the 4 year study and ongoing data collection should at least include 1) comparison of soil water sensors for monitoring establishment conditions for weeds and desirable species, and 2) seedling root growth potential of weedy and desirable species in relation to elevation and disturbance.

FIELD GERMINATION POTENTIAL OF CHEATGRASS (*BROMUS TECTORUM*) IN RELATION TO DISTURBANCE AND ELEVATION

Bruce A. Roundy, Brigham Young University, Provo, Utah; Jeanne C. Chambers, USDA Forest Service, RMRS, Reno, Nevada; Alison Whittaker, Utah Division Wildlife Resources, Ephraim, Utah; and Susan E. Meyer, USDA Forest Service, RMRS, Provo, Utah

Study Description: Over the past several decades, cheatgrass (*Bromus tectorum*) has been continually expanding in the sagebrush steppe ecosystem. Research on why cheatgrass is able to invade these communities has been limited. This study looks at how season, site, elevation, and disturbance affect germination potential of cheatgrass, as a function of seedbed soil water availability and temperature.

Methods: Plots were established in the spring of 2001 on 9 sites in Nevada and Utah. Three of the plots in both Nevada and Utah were located in sagebrush stands along an elevational gradient. In Nevada, the elevations were 1960, 2190, and 2380 m and in Utah were 1710, 2085, and 2274 m. The fourth sites were located in stands of crested wheatgrass (*Agropyron cristatum*) having elevations of 2065 m in Nevada and 1628 m in Utah. The final site was located in Utah in a stand of squirreltail (*Elymus elymoides*) at an elevation of 1597 m. Vegetation removal and burn treatments were applied in a factorial design to examine the separate and combined effects of perennial herbaceous vegetation removal and fire on seedbed environmental conditions. Individual study plots (3 m diameter) were located within each of the shrub-dominated study sites around a focal sagebrush and were usually 2 or more meters apart. For the crested wheatgrass and squirreltail study sites, plots were located within areas of relatively uniform grass cover. The removal treatments included leaving the herbaceous understory intact or spraying with glycophosphate (Roundup®) in spring of 2001 for complete kill. The burn treatments applied in fall 2001 included leaving the plot unburned or burning within 3.4 m diameter burn barrels around each plot, adding 4.5 kg of straw for consistent fuel loading, and lighting the plots with drip torches (Korfmacher et al. 2003). Three replicates of each treatment combination were applied per site (9 sites x 2 removal treatments x 2 burn treatments x 3 replicates = 108 plots). Also in fall 2001, subplots 1.5 m x 0.75 m within each of the 4 removal-burn treatment plots (live-unburned, live-burned, dead-unburned, dead-burned) in each replication were broadcast seeded with filled seeds (600 seeds/m^2) of cheatgrass.

In summer 2001, thermocouples and gypsum blocks (Delmhorst, Inc.) were buried in each of the 4 removal-burn treatment plots and within subplots left unseeded or seeded in fall to cheatgrass. Both sensor types were buried at depths of 1-3, 13-15, and 28-30 cm. Thermocouples to sense soil temperatures were installed in 2 replicates and gypsum blocks to sense water potential were installed in all 3 replicates of the treatments at each study site. Soil temperature and water potential sensors were read every minute and hourly averages recorded using Campbell Scientific, Inc. CR-10X microloggers. Hourly air temperatures from a thermister in a gill shield and total hourly precipitation from an electronic tipping bucket rain gage were also recorded at each study site.

Germination potential variables were calculated for 4 fall seasons (September

through November for 2001 through 2004) and for 4 spring seasons (March through June for 2002 through 2005). Gypsum blocks sense soil water potential to about -1.5 MPa (CSI 1983). Soil temperatures and water potentials from the 1-3 cm depth were used to calculate a number of environmental variables considered relevant to cheatgrass germination. Given a base temperature for germination of 0 ° C, the thermal time required for 50% germination of a population (D50) of imbibed seeds of cheatgrass ranges from 12 to over 100 degree days, depending on the incubation temperature and seed population (Hardegree et al. 2003, Taylor et al. 2004, Bair et. al 2005). A reasonable, average value for D50 for non-dormant cheatgrass is around 1000 degree hours or about 41.7 degree days. Wet degree days (WDD) were calculated by adding all hourly temperatures above 0 ° C for the entire time that the soil was wet (< -1.5 MPa) for a season and dividing by 24 hours/day. The number of potential germination wet periods (PGW) was calculated for each season by counting the number of times that the soil was wet and accumulated at least 41.7 degree days (1000 degree hours) typically required to germinate 50% of cheatgrass seeds (ref). The degree days for the maximum time (MDD) the soil was wet for a season was also calculated. To determine potential germination in time, wet degree days per day were calculated for fall and spring periods by adding up hourly temperatures over 0 ° C for each day that surface soil water potential was greater than -1.5 MPa at 1800 hours and dividing by 24 hours per day.

Average hourly thermocouple temperatures from the 2 replicates were used to calculate germination potential variables for each of the 3 soil water potential plot replicates for each site. Averages of all replicates for each treatment combination for a site were then analyzed in a mixed model (SAS Proc Mixed, Littell et al. 1996), with site considered random and year, removal, burn, and seed treatments considered fixed factors. Best unbiased linear prediction equations (BLUPS) were used to estimate germination potential values for sites for each year (Littell et al. 1996).

Results and Conclusions: Water-year precipitation increased with elevation and was least in Nevada in 2003-2004, least in Utah in 2001-2002, and highest for all sites in 2004-2005 (Fig. 1). An exception to the pattern of increasing precipitation with elevation was some fall or spring storms that produced similar precipitation at all sites.

The number of potential germination wet periods (PGW) and wet degree days (WDD) varied significantly ($P<0.0001$) by year for both fall and spring (Fig. 2). Potential for cheatgrass germination was greater in spring than in fall, but was sufficient for germination for all seasons during all years except for the fall of 2001 (PGW< 1). In general, lower elevation sites had greater cheatgrass germination potential than middle and upper sites, but all sites had sufficient PGW and WDD for cheatgrass germination for most seasons and years. Burning slightly increased the number of WDD, but unburned plots had sufficient PGW and WDD for cheatgrass germination (Fig. 3). The earliest date of potential cheatgrass germination varied greatly among years, and was later in the fall and spring at upper than lower elevation sites in Nevada (Fig. 4). Even though there was generally sufficient potential for cheatgrass to germinate on all sites, the upper sites had little actual cheatgrass establishment, as did the lower site in Utah. Seedling death associated with cold temperatures or drought may have limited establishment on these sites.

Management Implications: Soil temperatures and surface soil water availability were sufficient for potential cheatgrass germination in fall or spring on 9 sagebrush zone sites during 4 years of study. Because cheatgrass is well-adapted to germinate throughout the sagebrush zone, this zone must be managed to maintain competitive residual perennial herbaceous vegetation to reduce invasion. Although residual vegetation may not reduce potential germination, it decreases subsurface soil water availability (Whittaker et al. 2006) and nitrate (Blank et al. 2006), thereby limiting cheatgrass growth and seed production (Chambers et al. 2006). The end result is a reduction in cheatgrass invasion potential.

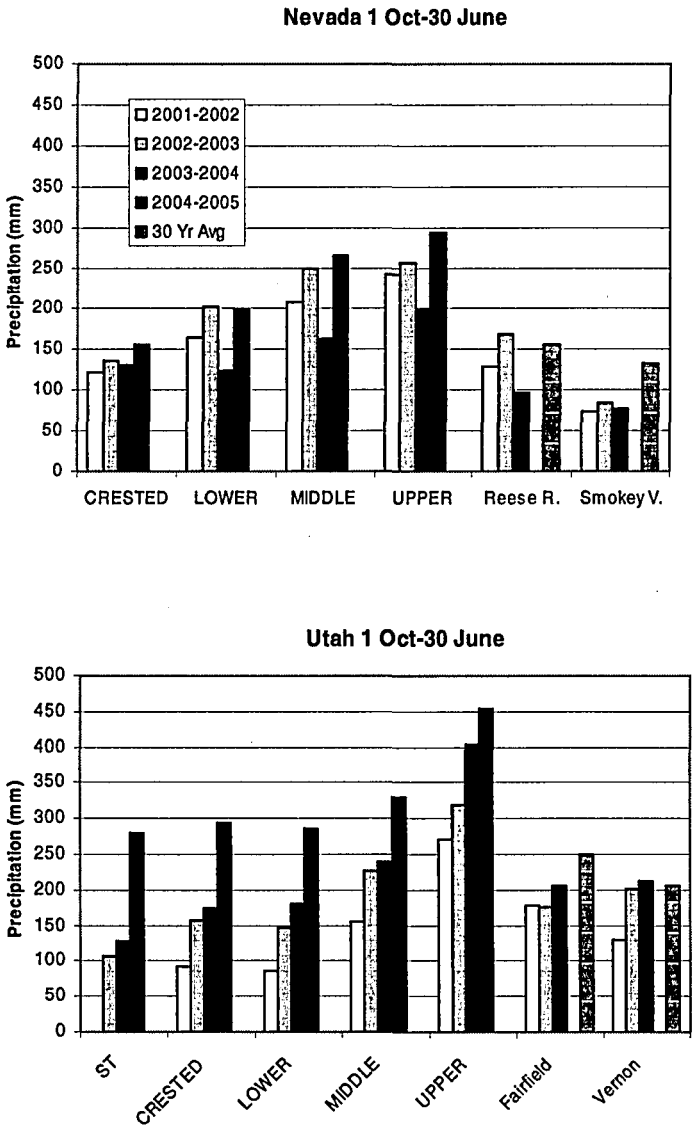

Figure1. Water-year precipitation for squirreltail (ST), crested wheatgrass, and lower, middle, and upper elevation big sagebrush sites in Nevada and Utah.

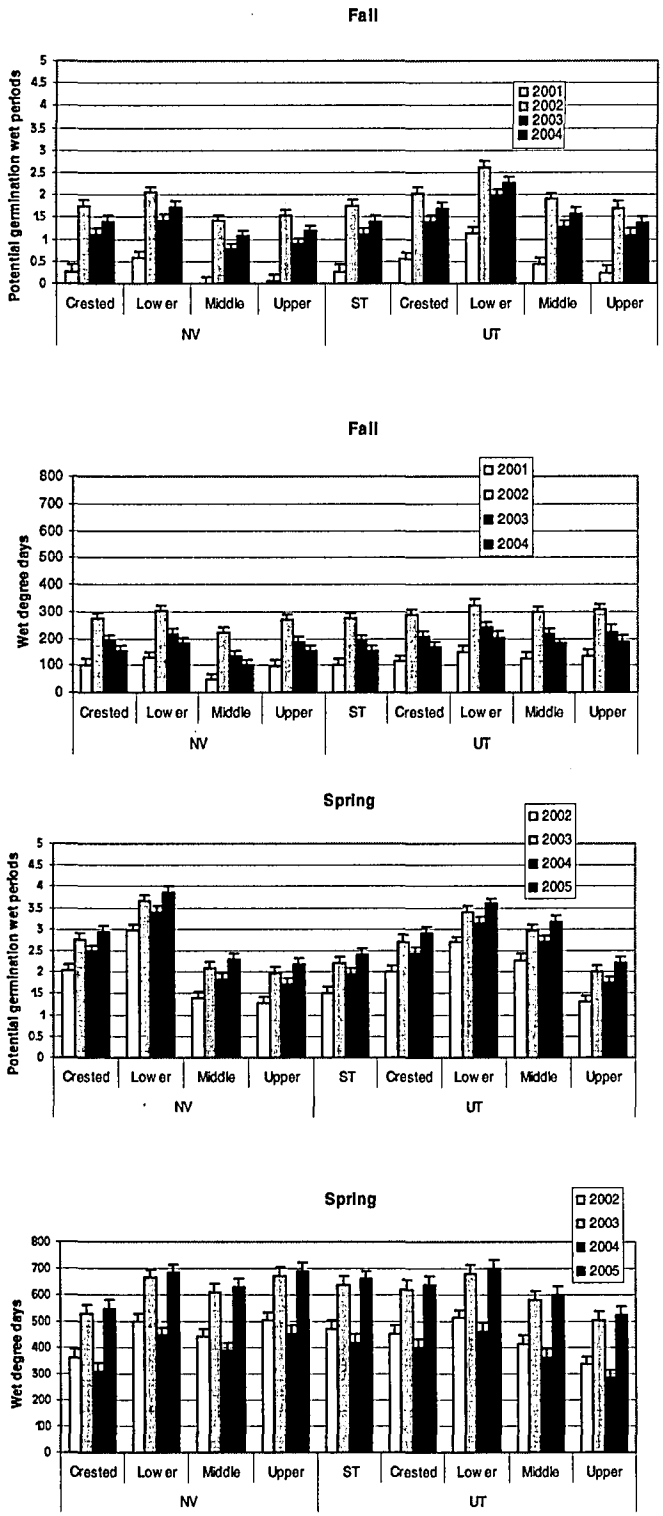

Figure 2. Potential germination wet periods and wet degree days for crested wheatgrass, squirreltail (ST), and lower, middle and upper elevation big sagebrush sites in Nevada and Utah.

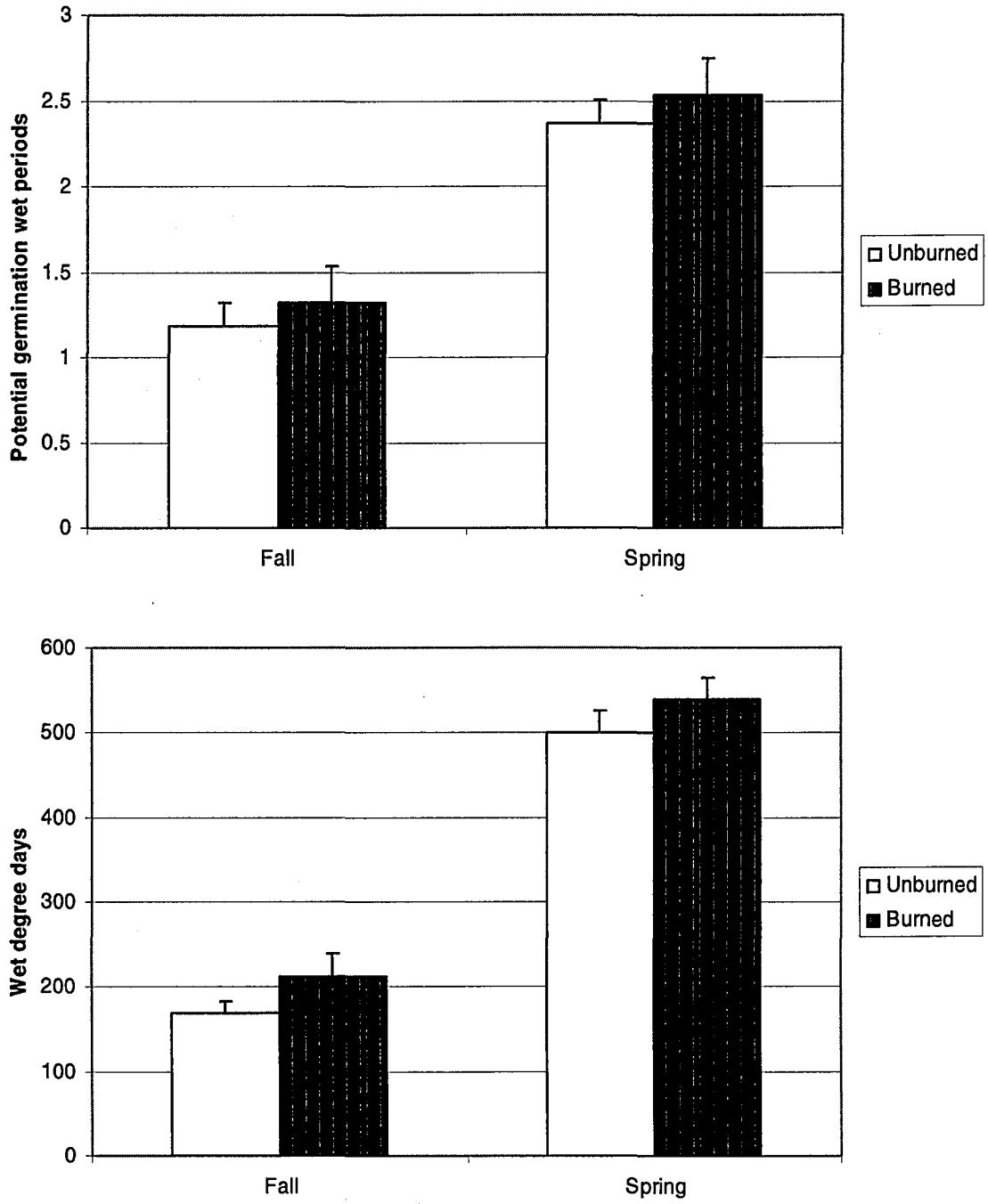

Figure 3. Potential germination wet periods and wet degree days for germination of cheatgrass in relation to fall burning on big sagebrush zone sites.

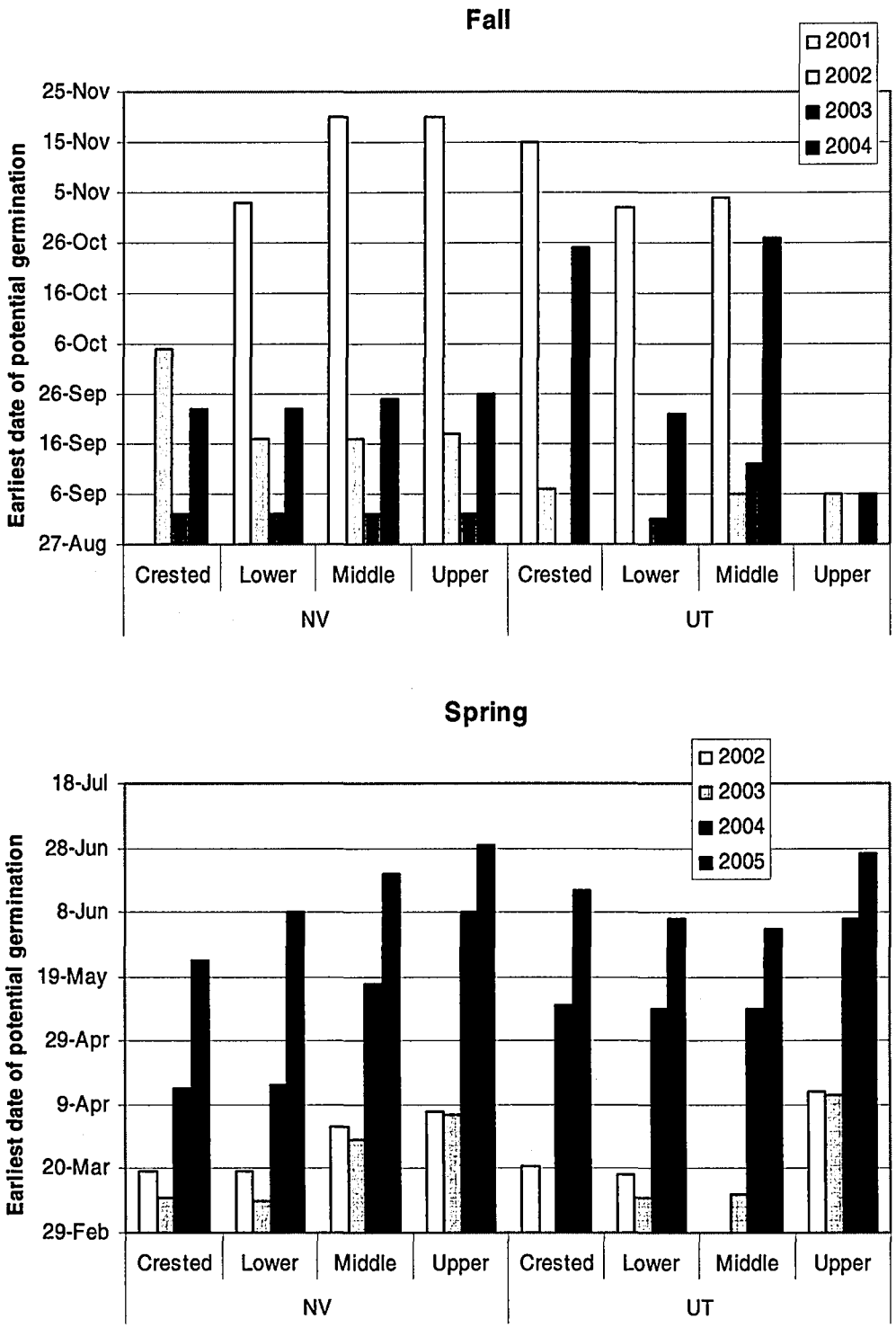

Figure 4. Earliest date of occurrence of sufficient wet degree days to germinate cheatgrass on crested wheatgrass and lower, middle, and upper elevation big sagebrush sites in Nevada and Utah.

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Whittaker, A., B. A. Roundy, J. C. Chambers, and S. E. Meyer. 2006. Soil water availability in relation to disturbance and elevation in the sagebrush zone. To be submitted to a refereed journal in 2006.

Products include:

Roundy, B.A., J.C. Chambers, A. Whittaker, and S. E. Meyer. 2006. Field germination potential of cheatgrass in relation to disturbance and elevation. Will be submitted to Rangeland Ecology and Management probably in October 2005.

Whittaker, A. 2006. Soil water availability in relation to disturbance and elevation in the sagebrush zone. MS thesis. Brigham Young University, Provo, Utah. – Alison may give you a different title for her thesis and subsequent paper.

Whittaker, A., B. A. Roundy, J. C. Chambers, and S. E. Meyer. 2006. Soil water availability in relation to disturbance and elevation in the sagebrush zone. To be submitted to a refereed journal in 2006.

EFFECTS OF HERBACEOUS SPECIES REMOVAL, FIRE, AND CHEATGRASS (*BROMUS TECTORUM*) ON SOIL WATER AVAILABILITY IN SAGEBRUSH STEPPE

Alison Whittaker and Bruce Roundy, Brigham Young University, Jeanne Chambers, USDA Forest Service, RMRS, Reno, Susan Meyer, USDA Forest Service, RMRS, Provo, Bob Blank, USDA-ARS, Reno, Stan Kitchen, USDA Forest Service, RMRS, Provo, and John Korfmacher, USDA Forest Service, RMRS, Fort Collins

Study Description: Over the past several decades, cheatgrass (*Bromus tectorum*) has been continually expanding in the sagebrush steppe ecosystem. There has not been a lot of research that examines why cheatgrass is able to invade these communities. This study looks at how changes in vegetation, and in consequence, changes in available soil water may play a part in this invasion. Available soil moisture is on of the main limiting factors in sagebrush steppe communities (Briones, Montana, and Ezeurra 1998). Many factors, such as vegetation, slope, aspect, and soil physical properties, can affect the total water availability (>-1.5MPa) in the soil. The objectives of this study were to determine the effects of elevation, differing amounts of vegetation, fire, and the presence of cheatgrass on total water availability in the soil.

Methods: In the spring of 2001 plots were setup on nine sites in Utah and Nevada. Three of the plots in both Utah and Nevada were located in sagebrush stands along an elevational gradient. In Utah the elevations were 5600', 6840', and 7460' and in Nevada they were 6400', 7180', and 7800'. The fourth sites in Utah and Nevada were located in a stand of crested wheatgrass (*Agropyron cristatum*) having elevations of 5340' and 6760', respectively. The final site was located in Utah in a stand of squirreltail (*Elymus elymoides*) at an elevation of 5240'. The treatments included a burn treatment (burned or not burned) and a vegetation removal treatment (intact or 100% removal). Within each combination of these two treatments, subplots were seeded with cheatgrass. Each treatment combination was replicated three times per site in a random complete block design for a total of 12 plots per site. The plots were circular with a diameter of 3.4m. The vegetation removal was accomplished by spraying the understory vegetation with Roundup in the spring of 2001. In the following October, the BLM and Forest Service fire crews carried out the burn treatments. Following the burn treatment, subplots within each plot were seeded with cheatgrass.

To measure soil moisture, gypsum blocks were installed in each plot both in the seeded subplot and in the unseeded area of the plot at three depths, 1-3, 13-15, and 28-30 cm. Thermocouples were also buried with the gypsum blocks to measure soil temperature. The sensors were read every minute and hourly averages were recorded onto CR-10X Campbell Scientific microloggers. Rain gauges and air temperature gauges were also installed on each site to record environmental conditions. The total days of available water for each treatment was totaled from April 1 to June 30 in 2002 and 2003. This is the period when cheatgrass and the other species on the site are actively growing and utilizing the soil moisture.

Results and Discussion:

Elevation

Elevation was a significant factor on total time of available water. When comparing the sagebrush sites in both Nevada and Utah, time of available water was significantly higher on the higher elevation sites than the lower elevation sites (Fig.1). There was an average of about 18 more days of available water on the upper sites than the lower sites. These results were expected because of the differences in precipitation on these sites (Table 1). The more resources you add to a system the more resources available.

Vegetation Removal

Vegetation removal did not significantly affect the time of available water at the 1-3cm depth over all sites. Time of available soil water, over all sites, at the 13-15cm and 28-30cm depths was significantly higher on the 100% removal plots than the intact plots (Fig. 2). These differences were only seen during the first growing season after the treatments (2002). At the 13-15cm depth on the sagebrush sites, the average total days of available water between April 1 and June 30 on the intact and 100% removal plots were 53.5 and 60.7 days respectively. At the 28-30cm depth averages on the sagebrush sites for the intact and 100% removal plots were 60.3 and 68.4 days respectively. When looking at each individual site, the middle Utah site was the only site that vegetation removal resulted in a significant difference in available water with a difference of about 20 day of available soil water.

Water loss from the soil can occur in two ways, evaporation and transpiration. When vegetation is lost less transpiration and more evaporation occurs (Coronato and Bertiller 1996). The change in transpiration mainly affects the lower portion of the soil profile, whereas the upper portion of the soil profile is mainly affected by evaporation. The upper portion of the soil profile still experiences evaporation, which can be higher due to less surface cover from vegetation. This may explain why the deeper portions of the soil profile on the 100% removal plots had more days of available water than the intact plots.

Burn Treatment

Results for the burn treatment were very similar to the removal treatment. The burn treatment only showed a significant effect on the sites during the first year and only at the 13-15cm and 28-30 depths (Fig. 3). Burning resulted in significantly more days of available water compared to the unburned plots. At the 13-15cm depth, the average total days of available water between April 1 and June 30 on the no burn and burn plots were 53.8 and 60.3 days respectively. At the 28-30cm depth averages for the no burn and burn plots were 60.5 and 68.2 days respectively. This is also probably due to the loss of vegetation and a decrease in transpiration. By the second growing season (2003) the burned vegetation had a chance to start growing back, which may explain why there was not a significant difference during the second season.

Seeding Treatment

The seeding treatment did not produce any significant differences. This was slightly unexpected since cheatgrass appears to out-compete other species by using up available resources (Aguirre and Johnson 1991). Cheatgrass establishment in Utah during the first year was very low which may help explain these results.

Removal/Burn

The interaction of both the removal and the burn treatments had similar results as each treatment alone in that significant differences were only seen in the first growing season (2002) and at the 13-15cm and 28-30cm depths. The intact/no burn plot had the fewest days of available water followed by intact/burn, 100% removal/no burn, and then 100% removal/burn (Fig. 4).

Conclusion:

The loss of vegetation through fire, drought, or grazing leaves extra resources available. This increase in available soil water may have an affect on the susceptibility of the community to invasion by weedy species. However the timing and the environmental conditions at the time of available water also play a part in the susceptibility of a community to weed invasion. In summary, water availability may increase, as vegetation is lost. Water availability also depends on the elevation and how much precipitation it receives. These changes in water availability can have an effect on the community and its susceptibility to weed invasion.

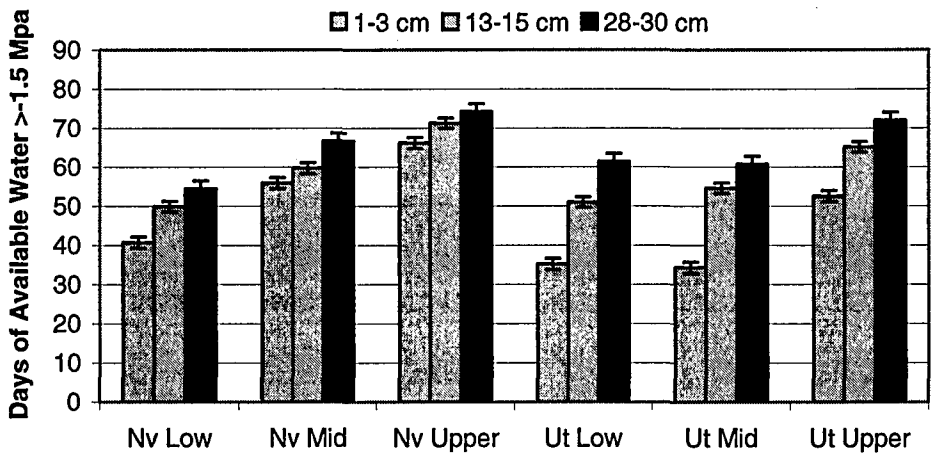

Figure 1. Average days of water availability at 1-3, 13-15, and 28-30 cm on all plots from April to June 2002 and 2003. Values are mean ± 1 SE. Days of available soil water were measured when soil matric potential was > -1.5 MPa.

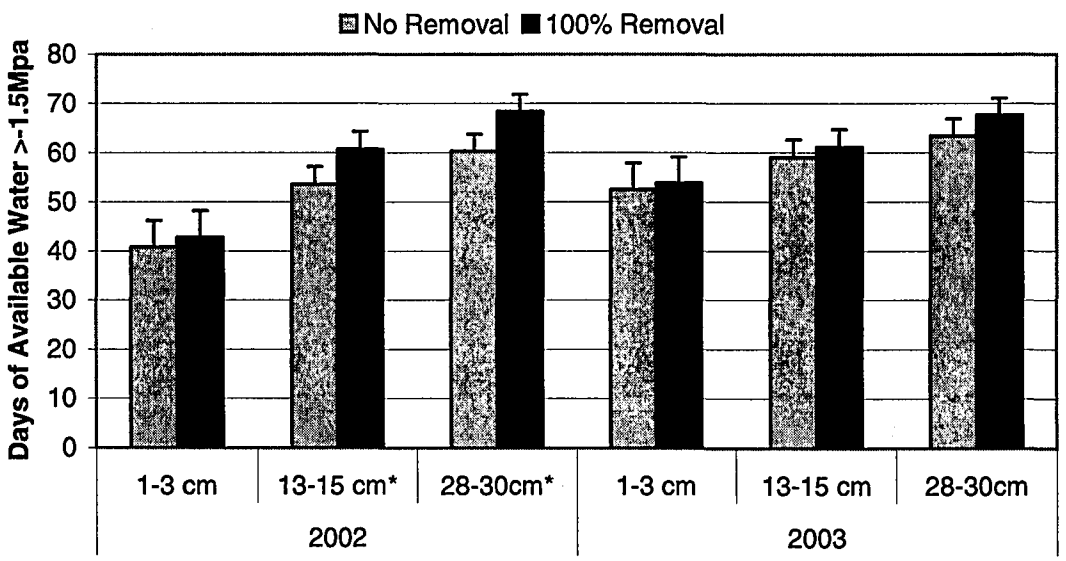

Figure 2. Average days of available water at 1-3, 13-15, and 28-30 cm on removal plots for the low, middle, and upper sites in Nevada and Utah. Values are mean ± 1 SE. Days of available soil water were measured when soil matric potential was > -1.5 MPa.
*Significant differences between removal treatments were only significant during 2002 at 13-15 and 28-30 cm.

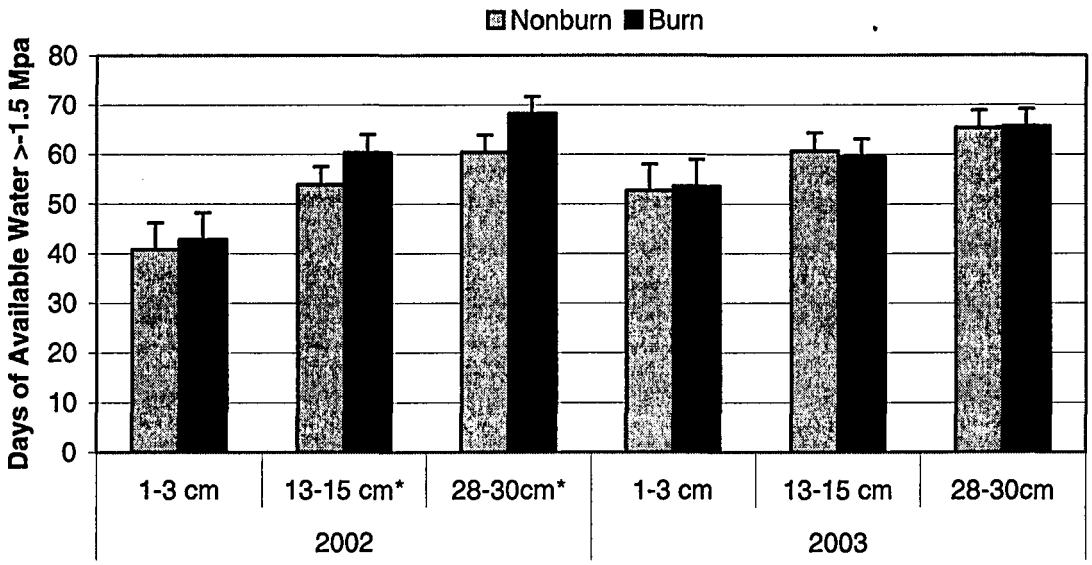

Figure 3. Average days of available water at 1-3, 13-15, and 28-30 cm on burn plots for the low, middle, and upper sites in Nevada and Utah. Values are mean $\pm$ 1 SE. Days of available soil water were measured when soil matric potential was > -1.5 MPa.
*Significant differences between nonburn and burn were only seen during 2002 at 13-15 and 28-30 cm.

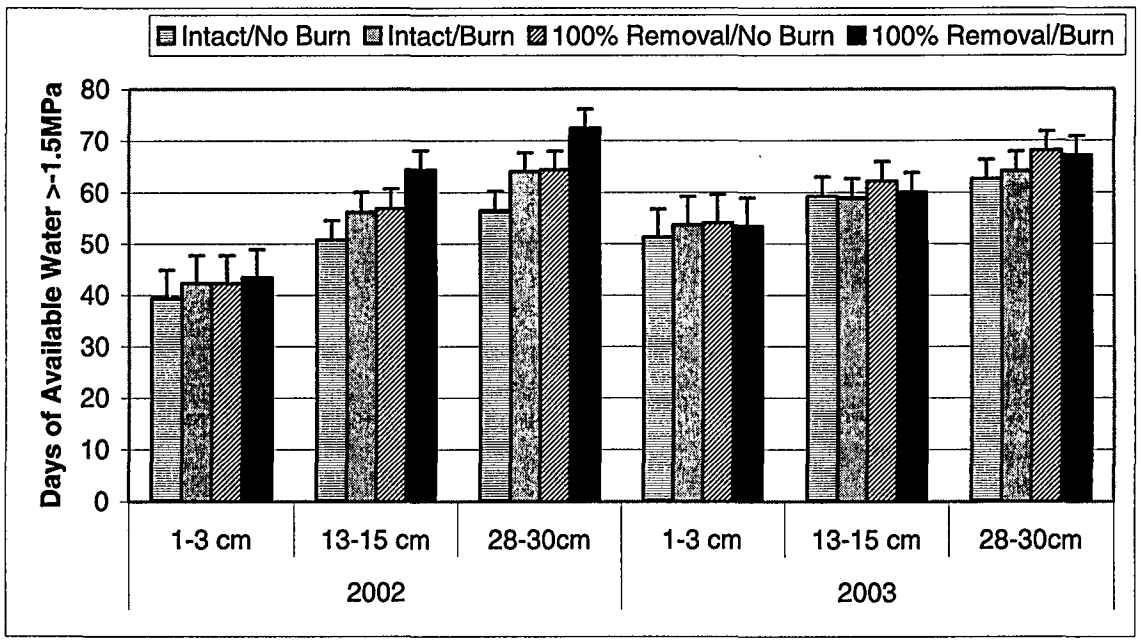

Figure 4. Average days of available water at 1-3, 13-15, and 28-30 cm on removal and burn plots for the low, middle, and upper sites in Nevada and Utah. Values are mean ± 1 SE. Days of available soil water were measured when soil matric potential was > -1.5 MPa.

Table 1. Precipitation for 2002 and 2003. *Closest long-term weather stations

		Precipitation (mm)					
		1 Oct-30 Jun			Annual		
Site		2002	2003	30 Yr Avg	2002	2003	30 Yr Avg
Nevada	*A. cristatum*	111.9054	139.908		144.436	194.775	
	Low	162.964	203.974		157.583	272.403	
	Middle	209.0773	252.123		187.4963	301.871	
	Upper	241.748	257.961		251.243	350.311	
	Reese River*	129.54	168.148	156.1801	149.352	209.804	203.1624
	Smokey Valley*	72.898	84.582	133.5019	88.646	116.078	183.1157
Utah	*A. cristatum*	91.904	158.596		124.013	232.7681	
	Low	83.63	147.354		193.216	244.674	
	Middle	154.518	226.874		201.347	322.73	
	Upper	198.7606	321.416		267.9143	505.551	
	Fairfield*	206.248	179.07	250.4402	332.6515	172.212	332.6515
	Vernon*	212.852	129.54	206.0442	272.9393	154.686	272.9393

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Products:

-Master's thesis in preparation

-Presentation at the national meeting for The Society for Range Management

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